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Large shocks in the volatility of the Dow Jones Industrial Average index: 1928-2010

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Abstract

We determine the events that cause large shocks in volatility of the DJIA index over the period 1928-2010, using intervention analysis and conditional heteroscedasticity model. We use a moving subsample window to take into account the periods with high or low volatility, allowing thus to identify large shocks as extraordinary movements perceived by the investors. We show that these large shocks can be associated with particular events (financial crashes, elections, wars, monetary policies, ...). We show that some shocks are not identified as extraordinary movements due to their occurring during high volatility episodes, especially the 1929-1934, 1937-1938 and 2008-2010 periods.

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1 Introduction

> *Black Monday, as October 19, 1987, became known, was not just another day; it was the single worst day (in percentage terms) in the Dow's history and therefore unique.* (Estrada, 2010).

Indeed, the Dow Jones Industrial Average (DJIA) index sustained a 22.6% loss on Black Monday. However, large daily swings that are neither unique, unusual nor as dramatic have a substantial impact on stock market returns. Events such as wars, terrorism, and bankruptcy are known as "black swans". According to Taleb (2007), a black swan is an event with three attributes: (i) It is an outlier, lying outside the realm of regular expectations because nothing in the past can convincingly point to its occurrence; (ii) it carries an extreme impact; and (iii) despite being an outlier, plausible explanations for its occurrence can be found after the fact, thus implying that it is explainable and predictable.

Failing to take explicit account of the fact that such extraordinary movements have occurred in the past – and will occur in the future – is therefore a serious omission (Friedman and Laibson, 1989). Several studies analyze the financial market reactions to major events, by focusing on one type of event. For example, Schwert (1989b, 1990) examine the effect of the 1987 stock market crash, Frey and Kucher (2000) and Choudhry (2010) study the impact of events during World War II, Amihud and Wohl (2004), Rigobon and Sack (2005) and Wolfers and Zitzewitz (2009) explore the impact of the Iraq War, Berkman, Jacobsen and Lee (2011) study the impact of rare disasters, Schwert (1981), Flannery and Protopapadakis (2002), Bomfim (2003), Birz and Lott (2011) and Rangel (2011) investigate macroeconomic announcements, Akhigbe, Martin and Whyte (2005) analyze the effect of the Worldcom bankruptcy, Chen and Siems (2004) and Chesney, Reshetar and Karaman (2011) study the impact of terrorism, Nierderhoffer, Gibbs and Bullock (1970), Reilly and Luksetich (1980), Foerster and Schmitz (1997), Santa-Clara and Valkanov (2003), Bialkowski, Gottschalk and Wisniewski (2008) and Jones and Banning (2009) look at the effect

of presidential elections, and Nierderhoffer (1971) explores the impact of Presidential illnesses. Most of these studies analyze the effects of events on financial markets where the dates are known, most often using event study methodology.

Other studies purport to identify major shocks due to "unknown" events that affect the stock markets before examining their implications. For example, Bloom (2009) uses the VXO index of implied volatility (1986–2008) as a proxy for uncertainty to show that uncertainty dramatically increases after major economic and political shocks. He defines majors shocks as those with volatility more than 1.65 standard deviations above the Hodrick–Prescott detrended mean of volatility. Wang et al. (2009) investigate the causes and effects of the eight largest stock market crashes (1962–2007). They define them as a minimum one-day decrease of 5% in the daily value-weighted market index returns of stocks included in the Center for Research in Security Prices (CRSP) database. Barro and Ursúa (2009) define stock-market crashes as cumulative multi-year returns of -25% or less when studying the relation between stock-market crashes and depressions on long-term data (1869–2006) from Global Financial Data. They include the variables in a rare-disaster model to explain the equity premium (Barro, 2006). Cutler et al. (1989) analyze the fifty largest stock movements in the S&P Composite Stock Index (1947–1987) which are defined as the largest one-day returns (daily changes).

Another way to identify black swans or (infrequent) large shocks is intervention analysis, introduced by Box and Tiao (1975) to attempt to statistically appraise these types of shocks. Intervention analysis is used to assess the impact of a known or unknown event on the time series. The main focus is to estimate the dynamic effect of such events on the series.[1] No attempt is made here to formally define a black swan. Intervention analysis forms the basis for many outlier modelling procedures. Outliers in economic time series have been studied and classified in different ways (Fox, 1972; Box and Tiao, 1975), following their dynamic patterns. The most important categories

[1] Balke and Fomby (1994), Charles and Darné (2006), and Darné and Charles (2011) use intervention analysis in a linear framework to identify large infrequent shocks in macroeconomic and financial times series.

of outliers observed in financial time series are additive outliers (AOs), which cause an immediate and one-shot effect on the observed series at time t, and innovative outliers (IOs), which have an effect propagating throughout the series (Balke and Fomby, 1994; Charles and Darné, 2005). A number of procedures have been developed to identify these outliers on linear models (e.g., Tsay, 1986; Chang, Tiao and Chen, 1988; Chen and Liu, 1993). Nevertheless, it is well known that the world is not linear, and neither are financial data. Such extreme movements (in returns) are potentially important in finance and financial economics, especially in modelling volatility of returns, which are an important key to risk management, derivative pricing and hedging, market making, market timing, portfolio selection, monetary policy making, and many other financial activities. Several authors consider outliers in nonlinear setting (Hotta and Tsay, 1998; Sakata and White, 1998; Franses and Ghijsels, 1999; Franses and van Dijk, 2000; Charles and Darné, 2005; Doornik and Ooms, 2005; Zhang and King, 2005).

In this paper, the detection and identification of large shocks in volatility of the DJIA results from intervention analysis based on a conditional heteroscedasticity model.[2] We determine when these (positive and negative) large changes in volatility of daily returns occur during this period. We use a moving subsample (10 years) window to take into account the different volatility levels of the DJIA in the detection of the large shocks, namely periods with high volatility and periods with low volatility. This approach allows thus to identify large shocks as extraordinary movements perceived by the investors. The larger changes in percentage have different consequences and perceptions when the market is within a high volatility period compared with a low volatility period or a stable period, especially in a context of uncertainty

[2]Autoregressive conditionally heteroscedastic (ARCH) models introduced by Engle (1982) and extended to generalized ARCH (GARCH) by Bollerslev (1986), have been developed to capture the two most important stylized facts of returns of financial assets, which are heavy-tailed distribution and volatility clustering. A number of studies have shown that a GARCH(1,1) model appears to model conditional variances adequately (see, e.g., Bollerslev, 1987; French, Schwert and Stambaugh, 1987; Akgiray, 1989; Schwert and Seguin, 1990).

about the future profitability of equities and their risk. We try to associate the date of each outlier with a specific (economic, political or financial) event that occurred near that date, and many of them seem to be associated with the same event patterns. We find that large shocks in volatility of the DJIA index spanning October 2, 1928 to December 31, 2010 are principally due to major financial crashes (1929, 1987, 1997-98, and 2008-09), US elections (i.e., Presidential and Congressional), wars (e.g., Spanish Civil War, World War II, Korean war, and Gulf war), monetary policy during recessions, macroeconomic news and declarations about the economic situation, terrorist attacks, politico-economic conflicts (e.g., Cuban missile crisis), bankruptcy and investigation (e.g., Worldcom), and regulation (e.g., First Glass-Steagall Act, National Industrial Recovery Act). We also find that some negative and positive high returns experienced by the DJIA are not identified as outliers, namely as extraordinary (rare) movements, due to the very high volatility of some periods (see, e.g., Officer, 1973; Schwert, 1989a). This can be explained by differing consequences and perceptions of the investors when the market is experiencing high volatility rather than low volatility or stability. Therefore, we use the iterative cumulative sums of squares (ICSS) algorithm proposed by Inclán and Tiao (1994) and improved by Sansó et al. (2004) to identify sudden shifts in volatility of the DJIA. We find different regime changes in volatility, especially episodes of high volatility occurring in 1929-1934, 1937-1938 and 2008-2010. Further, as described by Schwert (2011), we show that the period following the 2008 financial crisis (2008-2010) is associated with very high levels of volatility and is *de facto* short-lived (few years) in contrast to the prolonged periods (many years) of high volatility from 1929 to 1934.[3]

The paper is structured as follows: the DJIA index is presented in Section 2. Section 3 describes the methodology of intervention analysis based on a conditional heteroscedasticity model. The empirical framework is discussed in Section 4, along

[3]The very high level of volatility during the period following the 2008 financial crisis is *de facto* short-lived because our database ends in December 2010. More data are necessary to determine a volatility change at the end of the sample, which could thus characterize this period as short-lived or not.

with the events associated with infrequent large shocks in DJIA volatility. Section 5 presents volatility changes in the DJIA. The conclusion is drawn in Section 6.

2 The Dow Jones Average Index

The first Dow Jones Average Index, the precursor of the Dow Jones Industrial Average, was created by Charles H. Dow, Edward D. Jones and Charles Bergstresser in 1884. It was originally published in a daily financial newspaper the *Customer's Afternoon Letter*, which became the *Wall Street Journal* in 1889. They were the first to see the need for an index that could be used to gauge the activity of the New York Stock Exchange (NYSE) as a whole. The initial Dow Jones Average was based on a simple average calculated by adding up the component stocks' prices and dividing the total by the number of components. It began in 1884 with 11 stocks, mostly railroads, which were the first large national corporations. At that time, railroad stocks represented a key growth industry and, as such, were the only shares traded in heavy volume on the NYSE. It was not until the spring of 1896 that Charles Dow had developed his ideas to the point where he completely removed railroad securities from his general market Average and created two separate Averages: Industrials and Railroads.[4] At first, the Dow Jones Industrial Average (DJIA) was published irregularly, but daily publication in *The Wall Street Journal* began on October 7, 1896. It consisted of 12 stocks. In 1916, the DJIA expanded to 20 stocks; the number was raised again, in 1928, to 30, where it remains. Also in 1928, the Journal editors began calculating the average with a special divisor other than the number of stocks, to avoid distortions when constituent companies split their shares or when one stock was substituted for another. Through habit, this index was still identified as an "average".

[4]The Dow Jones Railroads Average first appeared on May 26, 1896. The original Railroad Average was replaced by the more generalized Transportation Average, so-called the Dow Jones Transportation Average (DJTA), after a number of trucking, airline, and air-shipping concerns were added to it in 1970. The last development was the fifteen-stock Dow Jones Utilities Average (DJUA), launched in 1929. See Dow Jones & Co. (1996) for a history of the Dow Jones Averages.

The DJIA is currently maintained and reviewed by the editors of *The Wall Street Journal*. For the sake of continuity, composition changes are rare, and generally occur only after corporate acquisitions or other dramatic shifts in a component's core business. When such an event necessitates that one component be replaced, the entire index is reviewed. As a result, multiple component changes are often implemented simultaneously. While there are no rules for component selection, a stock typically is added only if it has an excellent reputation, demonstrates sustained growth, is of interest to a large number of investors and accurately represents the sector(s) covered by the average. The DJIA is not limited to traditionally defined industrial stocks. Instead, the index serves as a measure of the entire US market, covering diverse industries such as financial services, technology, retail, entertainment and consumer goods. The 30 companies presently comprising the DJIA are all prominent in their industries; their stock is widely held by individuals and institutional investors. The calculation of the DJIA is weighted price rather than market capitalization. The component weightings are therefore affected only by changes in the stock prices, in contrast with other indices (such as Nasdaq 100 and S&P 500), whose weightings are affected by both changes in price and in the number of shares outstanding.

The DJIA is the most-quoted market indicator in newspapers, on TV and on the Internet, and one of most important indexes of the NYSE. Because of its longevity, it became the first to be quoted by other publications. Besides longevity, two other factors play a role in its widespread popularity: It is understandable to most people, and it reliably indicates the basic market trend.

3 Intervention Analysis Based on Conditional Heteroscedasticity Model

Outliers reflect extraordinary, infrequently occurring events or shocks that have important effects on macroeconomic and financial time series. There are several methods for detecting outliers based on intervention analysis as originally proposed

by Box and Tiao (1975). Here we will use the method described by Charles and Darné (2005), which extends the model developed by Franses and Ghijsels (1999) and Franses and van Dijk (2000) to take into account the events that cause an immediate, one-shot effect on the observed series (additive outlier, AO) or produces a temporary effect (innovative outlier, IO). This choice of dynamic patterns is inspired by Balke and Fomby (1994) and Tolvi (2001), among others, who show that AOs and IOs are the most important outliers observed in financial time series. This method allows us to examine the large shocks that affected the DJIA returns.

Consider the returns series ε_t, which is defined by $\varepsilon_t = \log p_t - \log p_{t-1}$, where p_t is the observed price at time t, and consider the GARCH(1,1) model

$$\varepsilon_t = z_t \sqrt{h_t}, \tag{1}$$

$$\varepsilon_t \sim N(0, \sqrt{h_t}), \qquad z_t \sim i.i.d.N(0,1),$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{2}$$

where $\alpha_0 > 0$, $\alpha_1 \geq 0$, $\beta_1 \geq 0$ and $\alpha_1 + \beta_1 < 1$, such that the model is covariance-stationary. The GARCH(1,1) model can be rewritten as an ARMA(1,1) model for ε_t^2 (see Bollerslev, 1986)[5]

$$\varepsilon_t^2 = \alpha_0 + (\alpha_1 + \beta_1)\varepsilon_{t-1}^2 + \nu_t - \beta_1 \nu_{t-1} \tag{3}$$

where $\nu_t = \varepsilon_t^2 - h_t$. The outliers can be modelled by regression polynomials as follows:

$$e_t^2 = \varepsilon_t^2 + \omega_i \xi_i(B) I_t(\tau) \qquad \text{with } i = 1,2 \tag{4}$$

where ε_t is a GARCH(1,1) process, $\xi_i(B)$ is the polynomial characterizing the outlier occurring at time $t = \tau$, ω_i represents its impact on the series, and $I_t(\tau)$ is an indicator function with the value of 1 at time $t = \tau$ and 0 otherwise.

The dynamic pattern is $\xi_1(B) = 1$ for an AO, and $\xi_2(B) = (1 - \beta_1 B)(1 - (\alpha_1 + \beta_1)B)^{-1}$ for an IO. An AO is related to an exogenous change that directly affects the series and only its level of the given observation at time $t = \tau$. An IO is possibly generated by an

[5]This analogy of the GARCH model with an ARMA model allows to directly adapt the method of Chen and Liu (1993) to detect and correct outliers.

endogenous change in the series, and affects all the observations after time τ through the memory of the process. It is considered that AOs produce an immediate effect whereas IOs produce a temporary effect.

A GARCH(1,1) model is fitted to ε_t in (1) and the residuals are obtained:

$$\eta_t = \frac{-\alpha_0}{1-\beta_1 B} + \pi(B)e_t^2 = \nu_t + \pi(B)\xi_i(B)\omega_i I_t(\tau) \tag{5}$$

where $\pi(B) = \big(1-(\alpha_1+\beta_1)B\big)(1-\beta_1 B)^{-1}$. The expression (5) can be interpreted as a regression model for η_t, i.e.

$$\eta_t = \omega_i x_{it} + \nu_t \tag{6}$$

with $x_{it} = 0$ for $i = 1,2$ and $t < \tau$, $x_{it} = 1$ for $i = 1,2$ and $t = \tau$, $x_{1,\tau+k} = -\pi_k$ (for AO) and $x_{2,\tau+k} = 0$ (for IO) for $t > \tau$ and $k > 0$.

The detection of the outliers is based on likelihood ratio statistics, given by:

$$\begin{array}{lll}
\text{AO:} & \hat{\tau}_1 = \big(\hat{\omega}_1(\tau)/\hat{\sigma}_\nu\big)\Big(\sum_{t=\tau}^{n} x_{1t}^2\Big)^{1/2} & \\
\text{IO:} & \hat{\tau}_2 = \hat{\omega}_2(\tau)/\hat{\sigma}_\nu & \\
\text{with} & \hat{\omega}_1(\tau) = \Big(\sum_{t=\tau}^{n} x_{1t}\eta_t\Big)\Big(\sum_{t=\tau}^{n} x_{1t}^2\Big)^{-1} \quad \text{and} & \hat{\omega}_2(\tau) = \eta_\tau
\end{array}$$

where $\hat{\omega}_i(\tau)$ ($i = 1, 2$) denotes the estimation of the outlier impact at time $t = \tau$, and $\hat{\sigma}_\nu^2$ is the estimated variance of the residual process.

We identify outliers by running a sequential detection procedure, consisting of outer and inner iterations. In the outer iteration, assuming that there are no outliers, a GARCH(1,1) model is estimated, and the residuals are obtained. The results from the outer iteration are then used in the inner iteration to identify outliers. The likelihood ratio test statistics for the two types of outliers are calculated for each observation. The largest absolute value of these test statistics $\hat{\tau}_{max} = \max_{1\le\tau\le n}|\hat{\tau}_i|$ is compared with a pre-specified critical value (based on simulation experiments), and if the test statistic is larger, an outlier is found at time $t = \tau$. When an outlier is detected, the effect of the outlier is removed from the data as follows: the observation e_t is adjusted at time $t = \tau$ to obtain the corrected ε_t^* via (4) using the estimated outlier impact $\hat{\omega}_i$, i.e. $\varepsilon_t^* = e_t - \hat{\omega}_i\xi_i I_t(\tau)$. This process is repeated until no more outliers can be found. Next,

we return to the outer iteration in which the GARCH model is re-estimated, using the corrected data, and start the inner iteration again. This procedure is repeated until no outlier is found.

4 Empirical study

4.1 Data description

In this section, we examine the DJIA stock market index spanning the October 2, 1928 to December 31, 2010, namely 20,714 observations. We consider the daily closing prices as the daily observations. Throughout the study, returns are calculated as:

$$R_t = (P_t - P_{t-1})/P_{t-1} \times 100$$

with R_t the return of each day, and P_t the index level at day t. Figure 1 plots the returns of the DJIA. This approach is justified because the thrust of the study is an investigation of market volatility. Subperiod analysis is also appropriate because stock return data may not exhibit stationary covariance over long periods (see Pagan and Schwert, 1990). Accordingly, in this study we consider a 10-year rolling window (about 2,500 observations).

Financial series contain a significant quantity of outliers which, if not treated adequately, could induce important specification, estimation and forecast errors. The presence of outliers may have undesirable effects on the estimates of the parameters of the equation governing volatility dynamics (see, e.g., Friedman and Laibson, 1989; Van Dijk et al., 1999; Mendes, 2000; Ng and McAleer, 2004; Charles, 2008), the tests of conditional homoscedasticity (see, e.g., van Dijk et al., 1999; Carnero et al., 2001, 2006), and the out-of-sample volatility forecasts (see, e.g., Franses and Ghijsels, 1999; Carnero et al., 2006; Catalán and Trívez, 2007; Charles, 2008).[6] Therefore, it is very important to acknowledge the presence of outliers in volatility.

[6]Estrada (2010) show that a few outliers have a massive impact on long term performance from the DJIA over the 1900-2006 period.

We apply the identification procedure of additive and innovative outliers in a GARCH model for the series of returns on a 10-year rolling window. This moving subsample window allows to take into account the different volatility levels of the DJIA, namely periods with high volatility and periods with low volatility, and thus to identify large shocks as extraordinary movements perceived by the investors. The larger changes in percentage have different consequences and perceptions when the market is within a high volatility period compared with a low volatility period or a stable period, especially in a context of uncertainty about the future profitability of equities and their risk. A change of -4% is not perceived in the same way by the investors when the market is within a high or a normal volatility period.

Table 1 gives descriptive statistics for the non-adjusted and outlier-adjusted return series. The non-adjusted returns are highly non-normal, i.e. showing evidence of negative excess skewness and excess kurtosis. They are leptokurtic (i.e., fat-tailed distribution). The variance of the index prices is thus principally due to infrequent but extreme deviations. The Lagrange Multiplier test for the presence of the ARCH effect clearly indicates that the prices show strong conditional heteroscedasticity, which is a common feature of financial data. In other words, there are quiet periods with small price changes and turbulent periods with large oscillations. The outlier-adjusted returns also exhibit excess skewness, excess kurtosis and conditional heteroscedasticity, although the excess kurtosis decreases dramatically.

4.2 A brief history of large shocks in DJIA volatility

All detected outliers are given in Tables 1-4, by timing, type, amplitude and t-statistics. A large number of outliers is found in the daily DJIA – 113 outliers – during the whole period. The probability of a large shock is 0.56%, with 58 negative (0.29%) and 55 positive (0.27%) large shocks. We also try to associate the date of each outlier with a specific (economic, political or financial) event that occurred near that date, presenting the outlier dates in chronological order.[7] In the following subsections, since

[7]The events associated with outliers are gathered from financial newspapers. Most of them are also found by Cutler et al. (1989) when analyzing the largest stock movements in the S&P Composite Stock

many of the identified outliers seem to be associated with the same event patterns we discuss the events using a classification of these patterns: financial crises, elections, wars, monetary policy during the recessions, macroeconomic news and declarations on the economic situation, terrorist attacks, bankruptcy and investigation, regulation, and politico-economic conflicts.

Further, Table 7 displays the 20 largest percentage changes and losses of the DJIA between October 1928 and June 2009. This table updates and completes the work of Schwert (1998) who present the 25 largest daily decreases.[8] The worst single day in percentage change is October 19, 1987, at -22.61%.

4.2.1 Financial crises

1929 Stock Market Crash. The crash of 1929 struck the NYSE between the October 24 and 29, 1929.[9] This event marks the start of the Great Depression. On the day of the crash on October 24, 1929 (Black Thursday), a record-breaking 13 million shares were traded, indicating panic. In the afternoon, five banks contributed about $20 million each to buy stock and restore confidence in the market. However, new accumulation of sale orders slumped on the market during the weekend, triggering a severe fall of the DJIA (-13.47%) on October 28, 1929 (Black Monday). This fall was broad based and did not spare securities of excellent quality (*blue chip* stocks). During the meeting, a conference of the bankers was held, yet it soothed the stock market only momentarily; investors believed thought that the banks were powerless to stop the fall.

On October 29, 1929 (Black Tuesday), the DJIA collapsed by -11.73%. This severe fall can be explained by the fact that in the middle of the meeting, panic occurred when the market learned of the failure of the Curb brokerage firm. The major banks and financial giants continued their efforts to stem the fall by buying large quantities of

Index on the 1947–1987 period.

[8] See also the Dow Jones website for a list of the largest daily (point and percentage) changes in the DJIA: http://www.djaverages.com.

[9] See, e.g., White (1990), Rappoport and White (1993), Galbraith (1997) and Bierman (1998) for a discussion of the 1929 stock market crash. See also Shachmurove (2012) for a historical overview of financial crisis in the US.

stocks to demonstrate their confidence in the market to the public, but their efforts were futile. In addition, the Morgan Bank and several other establishments announced that they would charge their customers a cover of only 25%. The wall Street Management Committee held a meeting during which the possibility of closing the Stock Exchange (next Saturday) was examined, but finally decided that the Saturday meeting would take place. The Federal Bank Reserve of New York appeared determined to lower the rate of the rediscount from 6% to 5% on Thursday. In the interim, it still reduced the rate of acceptances by $\frac{1}{8}$%. The general feeling was slightly less pessimistic. The investors believed that the support actions of the banks would be effective.

Wall Street began to recover from this crisis on October 30, 1929 (+12.34% for the DJIA), nearly offsetting the fall of the previous day. This recovery is due to massive purchases carried out by banks, investment trusts and insurance companies. The governors of the Stock Exchange decided to close on Friday and Saturday to allow the personnel to rest.

A new fall of the DJIA (-9.92%) on November 6, 1929, is due to an accumulation of selling orders over the holiday – Wall Street had taken its first day off in more than two weeks. Demand was limited, and the decline consequently started with the opening of business. A recovery occurred on November 14, 1929 (+9.36% for the DJIA), which can be explained by the announcement of Treasury Secretary Andrew Mellon that 1% reduction in income taxes would be proposed because of the government's conviction that the economic and financial conditions would remain perfectly healthy.

On June 22, 1931, the DJIA rose to 11.90% which can be attributed to President Herbert Hoover's proposal of a one-year moratorium on $250 billion of war debt owed to the US government by foreign powers. This plan was regarded as the most constructive economic development in two years, and was expected to stabilize international conditions tremendously. The poor performance of a number of European Stock Exchanges and the failures of some US banks may explain the loss recorded by the DJIA (-10.74%) on October 5, 1931. The following day, a strong rise occurred, driven by the noise of the formation of a powerful banking syndicate whose the

aim was to repossess some assets immobilized in several large financial institutions (+14.87% for the DJIA).

The falls during the previous days and the noise of the constitution, by the banks, of support funds of $1 billion caused the DJIA to rise sharply (+9.35%) on December 18, 1931.

1987 Stock Market Crash. On October 16, 1987, the DJIA fell −4.60% due to the announcement of the higher than expected US trade deficit in August ($15.6 billion). This triggered an immediate devaluation of the dollar despite intervention by the central banks.[10] Further, the Marine Midland Bank (19th US bank) announced that it raised, its prime lending rate (from 9.25% to 9.75%), as had the Chemical Bank, sparking a fear of higher interest rates.

On October 19, 1987, the DJIA sustained a −22.61% collapse (the largest one-day drop in the history of major stock market indexes from 1928 through the end of 2010), known as "Black Monday". This spectacular fall can be explained by the declarations of Treasury Secretary James Baker on the week-end, threatening Germany, which raised its interest rates, that it would decrease the dollar further. In this case, the Louvre Accord on the stabilization of currency values could be called into question. Therefore, the investors feared a new fall of the dollar and that the government did not support the dollar. The situation was worsened by the Iran-American conflict in the Persian Gulf.

The NYSE rises (+5.88% for the DJIA) on October 20, 1987, after the Chemical Bank and the Marine Midland Bank announced that they would lower their prime lending rate (from 9.75% to 9.25%), thus prompting investors to execute important buy orders, especially concerning quality stocks (ATT, General Electric, IBM, Exxon and General Motors). Moreover, the declaration by the Fed's Chairman Alan Greenspan reassured investors because the monetary authorities wanted to avert failure by banks or financial institutions, and place priority on the need for liquidities. The fight against inflation

[10] See Schwert (1989b, 1990) and Carlson (2006) for a discussion of the 1987 stock market crash.

and the support of the dollar were not major concerns.

On October 20, 1987, the DJIA continued to rise by $+10.15\%$ due to the additional decline of interest rates and President Ronald Reagan's stated intention to seek, jointly with Congress, the means of reducing the budget deficit. For investors, this implied the shift from an anti-inflationary policy to an anti-recession policy.

The fall of the DJIA (-3.82%) on October 22, 1987, can be explained by the tensions in the Persian Gulf (Iranian attack on a Kuwaiti oil terminal) and by analysts' alarmist forecasts of lower stock prices, despite the decline in the bank base rates. However, the stock exchange authorities limited the damages by requiring the NYSE to suspend the use of computer programs. The NYSE also decided to close Wall Street two hours earlier in the following days.

The DJIA recorded important losses (-8.04%) on October 26, 1987, following the reopening of the Hong Kong stock market (after being closed for one week). The NYSE announces that it would continue to close two hours early each day for the remainder of the week. The meeting of the President Ronald Reagan with the leaders of Congress on the federal deficit reduction apparently did not allay investors' fears.

The DJIA rebounded ($+4.96\%$) on October 29, 1987, due to four factors: (i) lower stock prices, (ii) falling interest rates, (iii) actions on the federal budget deficit, and (iv) the stabilization of the dollar. At least \$2 billion were bought by central banks (including Germany, England, Switzerland and Japan) to slow the fall of the dollar. Treasury Secretary James Baker reaffirmed that the US supports the Louvre Accord, ensuring the stabilization of the dollar.

On November 11, 1987, the DJIA plunged (-4.03%) due to the fall of the dollar, which caused fear of inflationary pressure.

1997-1998 Asian and Russian Crises. The Asian crisis started in Thailand with the financial collapse of the Thai baht in July 1997, and spread through the economies of Southeast Asia. Notably, the Hong Kong Stock Exchange fell steadily (the Hang Seng index lost 33.4% in eight days). Wall Street suffered accordingly, with a loss of 7.18%

for the DJIA on October 27, 1997. This plunge obliged the NYSE to stop quotations temporarily; it was the first time in US history that these mechanisms, adopted after the crash of 1987, were applied.[11]

The Russian crisis (also called the "Ruble crisis") was triggered by the Asian financial crisis and entailed a collapse of the Russian currency (ruble) along with a default of the short-term Russian Government Treasury Bills (the GKO). This caused the Long Term Capital Management (LTCM) hedge fund to default on several billion dollars of financial contracts. On August 26, 1998, the Russian Central Bank terminated ruble-dollar trading on the MICEX (Moscow Interbank Currency Exchange). On August 27, 1998, the strong fall of the DJIA (-4.19%) can be explained by the collapse of the Russian stock exchange market, but also by the appointment of a new government, whereas the economies of Eastern Asia (except for Taiwan and China) officially entered a recession. Consequently, investors increasingly feared a failure by Russia to repay its loans, coupled with possible contagion of the crisis towards other emerging markets, in particular in Central Europe and Latin America. This would inevitably erode the profits of US companies. The strong fall of the DJIA (-6.37%) on August 31, 1998, can be explained by a combination of the deterioration of the Russian and Asian crises along with the announcement of bad economic news, namely the declines of both firm profits and household consumption in July (-0.2%), which confirmed the slowdown of growth in the US.

Wall Street rebounded with a very strong trading volume of 1,212 billion shares, driving an increase of the DJIA (+3.82%) on September 1, 1998.

[11] In response to the market crisis of October 1987 the NYSE instituted circuit breakers to reduce volatility and promote investor confidence. When the DJIA loses 350 points, quotations are suspended for half an hour. The suspension is increased to one hour if the loses are of 550 points. These measurements are supposed to give the operators time to reflect and calm themselves during periods of high market volatility. The SEC approved amendments to Rule 80B (Trading Halts Due to Extraordinary Market Volatility) – effective on April 15, 1998 – which revised the halt provisions and the circuit-breaker levels. The trigger levels for a market-wide trading halt were set at 10%, 20% and 30% of the DJIA, calculated at the beginning of each calendar quarter, using the average closing value of the DJIA for the prior month, thereby establishing specific point values for the quarter.

2008–2009 Global Financial Crisis. The House of Representatives rejected the bailout plan proposed by Treasury Secretary Henry Paulson, called the Paulson Plan or the Troubled Asset Relief Program (TARP), intended to stabilize the financial system on September 29, 2008, causing the severe fall of the DJIA (-6.98%).[12] The Paulson plan is supported by the Emergency Economic Stabilization Act of 2008,[13] enacted in response to the subprime mortgage crisis, authorizing the Treasury Secretary to spend up to $700 billion to purchase distressed assets, especially mortgage-backed securities, and inject capital into banks.

The strong fall of the DJIA (-7.33%) on October 9, 2008, resulted from investor panic following the contagion of the financial crisis in Europe. The interventions of the US and European governments to suppress the liquidity crisis of the banks caused the strong rise of the DJIA (+11.08%) on October 13, 2008. The European countries offered €1700 billion to save the financial system and the US Treasury ban to purchase distressed assets in line with the Paulson Plan. The DJIA fell considerably (-7.87%) on October 15, 2008, after the announcement of dismal economic statistics, prompting a fear of recession. The fears of a severe and long recession due to the publication of US firms' third quarter results can explain the losses of the DJIA (-5.70%) on October 22, 2008. The DJIA rebounded (+10.88%) on October 28, 2008, fueled by purchase opportunities and the the possibility of the Fed's cutting interest rates.

The rise of Wall Street (+6.67% for the DJIA) on November 13, 2008, can be explained by the issue of US Treasury bonds which are in great demand in a period of uncertainty. The lack of an agreement in the Senate on the bailout of the automobile industry along

[12] See, e.g., Bartram and Bodnar (2009) and Mishkin (2010) for a discussion of the 2008–2009 financial crisis.

[13] The Senate debates and votes on a revised version of the Emergency Economic Stabilization Act of 2008 (EESA 2008) on October 1, 2008, The House of Representatives votes in favor of the legislation on October 3, 2008, and the President George W. Bush signs the bill into law within hours of its enactment. The law has three major divisions, Division A: the Emergency Economic Stabilization Act of 2008; Division B: Energy Improvement and Extension Act of 2008, and Division C: the Tax Extenders and Alternative Minimum Tax Relief Act of 2008.

with the dismal economic statistics (especially employment and industry), raising fears of deflation, can explain the decline on Wall Street (-5.56% for the DJIA) on November 20, 2008. The rise of the DJIA (+6.54%) on November, 21, 2008, is attributable to the following factors: (i) the announcement of a new government's financial rescue plan ($700 billion over two years); (ii) the government's rescue plan for Citigroup (with guaranties against losses on $306 billion in risky loans and securities); and (iii) the President Barack Obama's plans to name New York Federal Reserve President Timothy Geithner as Treasury Secretary.

The higher than expected decrease in the economic activity index in the manufacturing sector (the Institute for Supply Manufacturing index), suggesting a severe recession, triggered the fall of the DJIA (-7.70%) on December 1, 2008.

The rise of the DJIA (+5.80%) on March 10, 2009, is caused by the announcement of earnings in January and February for Citigroup and Fed Chairman Ben Bernanke's reaffirming of US government's commitment to support the financial system, buoyed bank stocks. The announcement of the bailout plan by Treasury Secretary Timothy Geithner can explain the strong rise of the DJIA (+6.84%) on March 23, 2009. The Geithner Plan consists in liberating the US banks from their toxic assets through a private-public investment program to purchase $500 billion to $1 trillion worth of distressed assets.

Note the fall of the DJIA (-3.29%) on February 27, 2007, can be explained by the fall of Shanghai Stock Exchange due to the tightening of monetary policy of the Chinese government. Further, Alan Greenspan, former Fed's Chairman, declares that a recession could affect the US economy. Finally, investors are concerned about the shortcomings of high-risk loans ("subprime mortgage") granted to households less creditworthy. The two largest mortgage agencies Freddie Mac and Fannie Mae announced that they would tighten the criteria for this type of refinancing loans.

4.2.2 Elections

Presidential elections. On September 21, 1932, the declarations by Franklin Roosevelt, the Democrat presidential candidate, dispelled the apprehensions felt by Wall Street and caused a strong rise in the DJIA (+11.37%). Indeed, the possible victory of the Democrat party has been considered a positive factor because investors anticipate measures that revive the economy (such as revision of custom tariffs). The rise of the DJIA (+4.37%) on November 7, 1940, can be attributed to the re-election of the President Franklin Roosevelt, who ran against Republican Wendell Willkie. The Democrat majority to the Senate and the House of Representatives was also preserved. The victory of Democrat Harry Truman over Republican Thomas Dewey on November 3, 1948, caused a decline on Wall Street (-3.85% for the DJIA) because investors expected a Republican win. The fear of reestablishment of income taxes by the Democrats can explain the fall of the DJIA (-3.34%) on November 5, 1948.

Congressional elections. Investors considered Republican victories in elections of the Senate and the House of Representatives on November 6, 1946, as the announcement of a possible deflation policy, prompting a drop in the DJIA (-3.17%).

The DJIA advance (+4.25%) on November 3, 1982, is due to the investors relief over the small Democrat victory in the House of Representatives, implying that the policy implemented by the Ronald Reagan administration would remain intatc (lower inflation and interest rates).[14]

President's Health and Assassination. The large movements of the stock market in September and October 1955 are due to the illness of President Dwight Eisenhower. The announcement of his heart attack prompted a plunge in the DJIA (-6.54%) on September 26, 1955. In the following days, Wall Street responded strongly to major news concerning the President's health: good news on September 27, 1955 (+2.28% for the DJIA) and bad news on October 10, 1955 (-2.92% for the DJIA).[15]

[14] Nierderhoofer et al. (1970) show that the markets tend to rise when the chances of a Republican victory increase.

[15] Nierderhoffer (1971) studies the relation between Presidential illnesses and stock prices. He shows that there is a strong and consistent stock price movement in the case of death or serious illness

The assassination of President John F. Kennedy in Dallas triggered the fall of the DJIA (-2.89%) on November 22, 1963. The governor of the NYSE closed the market 30 minutes early due to huge selling orders. The arrest of President Kennedy's assassin can explain the increase on Wall Street on November 26, 1963 (+4.69% for the DJIA), coupled with along the confidence in Vice-President Lyndon Johnson.

4.2.3 Wars

Spanish Civil War. The political situation in Europe, especially the civil war in Spain (the Nationalists marched on Barcelona and conquered Catalonia a few days later), and the deceleration of industrial activity can explain the fall of the DJIA (-5.52%) on January 23, 1939.

World War II. On October 5, 1937, the DJIA plummeted by -5.33% due to the interpretations of the speech by President Franklin Roosevelt in Chicago concerning the positions of the US regarding a possible international conflict. Indeed, the *Quarantine Speech* given by the President Franklin Roosevelt called for an international "quarantine of the aggressor nations" as an alternative to the political climate of American neutrality and isolationism that was prevalent at the time. The speech was a response to aggressive actions by Italy and Japan, and suggests the use of economic pressure, a forceful response, but less direct than outright aggression.

After the invasion of Poland by Germany on September 1, 1939, Australia, France, New Zealand and United Kingdom declared war on Germany on September 3, 1939. Therefore, on September 5, 1939, traders executed a high volume of purchases to benefit from "war boom" prices, propelling a rise in the DJIA (+9.52%).[16] The fall of the DJIA (-4.06%) on September 17, 1939, was caused by the invasion of Poland

of a president. Nierderhoffer finds that out of five president's sickness from 1916 to 1964, Dwight Eisenhower's sickness affected securities prices the most.

[16]Choudhry (2010) investigates the potential effects of the WWII events on the movements of the DJIA stock price index and returns volatility. Events during a war affect the equity markets in two ways: (i) it can increase or decrease the price of shares and the returns volatility, (ii) it can alter the uncertainty of the investors about the future profitability of the equities and their risk.

by the Soviet Union (under the pretext of protecting the Ukrainian and Belorussian minorities). The successive falls of the DJIA (-4.93%, -6.80%, -4.78%, and -6.78%) between May 13 to 21, 1940, are due to World War II in Europe, notably the flight of Queen Wilhelmina of the Netherlands and her government to London, the surrender of the Dutch army, the flight of the Belgian government after Brussels fell to German forces and the fact that German forces reached the English Channel. The declaration of President Franklin Roosevelt concerning the material help accorded to the Allies prompted a rise in the DJIA (+4.73%) on June 12, 1940.

Korean War. The falls of the DJIA on June 1950 can be explained by the Korean War. North Korea attacked South Korea on June 25, 1950, signaling the outbreak of the Korean War (-4.64% for the DJIA), and North Korean tanks entered Seoul on June 27, 1950 (-3.71% for the DJIA), prompting investors to fear a long war.

Gulf War. The rise of the DJIA (+4.57%) on January 17, 1991, was caused by Gulf War I, with the launching of the operation Desert Storm, in particular with the announcement of the success of the US air raids against Iraq.

4.2.4 Monetary Policy during Recessions[17]

1937-38 Recession. President Franklin Roosevelt's opposition to the monetary respite proposal caused a resurgence of speculation. The DJIA advanced significantly (+7.59%) on June 19, 1933.

1969–1970 Recession. The increase in the DJIA (+3.85%) on August 16, 1971 is due to the anti-inflationary program of the President Richard Nixon, which specifies a series of drastic economic measures (tight monetary policy) including a wage-price freeze, intended to lift the US out of its 1969–1970 recession.

1973–1975 Recession. The rise of the DJIA (+3.64%) on July 12, 1974, can be explained by three factors: (i) a decline in bank loans, (ii) the keeping of the prime rate by the First National City Bank (2nd US bank), and (iii) the announcement of the

[17] See Mishkin and White (2002) for a discussion of the implications for monetary policy of the stock market crashes.

slowdown of wholesale prices in June, implying lower inflation.

The expectations that President Gerald Ford would announce strong anti-inflationary measures, and the investors's decision to cut the prime rate (-0.25 points) can explain the increase in the DJIA (+3.94%) on October 7, 1974. These expectations are confirmed on October 9, 1974, with the rise of the DJIA (+4.71%) because the economic proposals of President Gerald Ford should reduce interest rates by reducing budgetary expenditures by $5 billion, and curb inflation by allocating $3 billion to construction loans to stimulate production.[18] The increase in the DJIA (+4.02%) on October 29, 1974 can be explained by the decline of short-term interest rates along with lower oil prices.

The further decline of short-term interest rates along with a favorable IBM stock price following its win of the appellate antitrust case caused the DJIA to rise (+3.91%) on January 27, 1975.

1980 Recession. The fall in short-term interest rates (many major banks reduced their prime lending rates from 20% to 19.5%) and the hope of slowing inflation stoked the DJIA (+4.05%) on April 22, 1980.

1981–1982 Recession. The rise of the DJIA (+4.05%) on August 17, 1982, can be explained by the interest rate decline and the debt crisis due to the announcement by Latin American countries, especially Mexico, that they could not repay their foreign debt. The rise of the DJIA (+3.66%) on August 20, 1982, followed further falls in US interest rates and cuts in prime rates at large US banks (the Chase Manhattan Bank and the Chemical Bank drop their prime lending rate from 14% to 13.5%). Furthermore, Congress passes President Ronald Reagan's bill intended to increase taxes by $98.3 billion and thus reduce federal budget deficits. An expectation of further declines in interest rates to help the economy recover can explain the rise of the DJIA (+4.09%) on October 6, 1982. The fall of the DJIA (-3.52%) on October 25, 1982, can be explained by investors' disappointment over the Fed's failure to cut discount rates, which might

[18]The failure of the Franklin National Bank on October 8, 1974, due to mismanagement and fraud, did not trigger a strong loss in the DJIA (-0.8%). This failure was the largest banking collapse in US history.

have led to tightening of credit terms.

1982-1990 Expansion. The fall of the DJIA (-4.61%) on September 11, 1986, can be explained by a fear of higher interest rates and inflation due to economic conditions in the US. Further, foreign governments refuse to lower interest rate.

1991–2001 Expansion. On September 8, 1998, the Fed's Chairman Alan Greenspan announces that the return of inflation is no longer the foremost danger for the US, thus implying that a relaxation of monetary policy could be envisioned. This possible easing of the US monetary policy caused large gains in the DJIA (+4.98%).

The unexpected reduction by the Fed of its two principal interest rates by 0.25%, encouraged the markets to buy in great volume, triggering a rise in the DJIA (+4.15%) on October 15, 1998. This easing of monetary policy was intended to stimulate the economic growth in a context of controlled inflation.

2001 Recession. Investors feared that the Fed would increase its interest rates to avoid a return to inflation and prevent the risk of the US economy's overheating.

4.2.5 Macroeconomic News and Declarations on the Economic Situation

1929-1932 Recession. The fall in grain prices affected the DJIA (-7.15%) on October 5, 1932. The rise of the DJIA (+3.58%) on October 15, 1946, is due to the deregulation of meat prices, which investors considered as a possible precursor of further deregulation.

1937-1938 Recession. The unfavorable report by the American Iron and Steel Institute on the activity of steel-works and a fall in purchases of agricultural produce by American consumers can explain the decline recorded on September 10, 1937, by the DJIA (-7.20%). On October 20, 1937, the possible readjustment of the tariffs of goods by the Interstate Commerce Commission generates a recovery of the DJIA (+6.08%), driven by railroad securities. The fall of the DJIA (-5.86%) on November 19, 1937, was caused by uncertainties relating to the evolution of the economic situation, following the publication of economic statistics.

1938-1945 Expansion. On April 9, 1943, President Franklin Roosevelt's anti-inflation

order governing prices and wages can explain the drop in the DJIA (-3.17%).

1946-1948 Expansion. The fall of the DJIA (-4.29%) on February 25, 1946, is due to multiple factors: the fear of difficulties in adjusting wages and prices, the threat of inflation, strikes, and the international situation. The declines in the DJIA on September 3 (-5.56%) and 9 (-4.41%), 1946, can be explained by labor unrest in the maritime and trucking industries. The coal strike ended on December 9, 1946, after 17 days, causing gains in the DJIA (+3.15%). The fall of the DJIA (-3.89%) on April 14, 1947, can be explained by the worsening of the economic situation and the fear of new strikes.

1957-1958 Recession. On October 23, 1957, the DJIA increases (+4.13%) following the declarations by President Dwight Eisenhower in support of the economy.

1961-1969 Expansion. The large movements in May and June 1962 can be explained by the economic situation. President John F. Kennedy forced the rollback of a steel price hike, which may explain the fall of the DJIA (-5.71%) on May 28, 1962, because investors saw this decision as a rethinking of the principle of free enterprise. The rise of the DJIA (+4.69%) on May 29, 1962, may be due to the declarations by Treasury Secretary Douglas Dillon reassuring the public about the economic situation. However, bad economic news caused the DJIA to slump (-2.84%) on June 4, 1962. Finally, President John Kennedy's intention to lower income taxes can explain the rise of the DJIA (+3.79%) on June 28, 1962.

1969-1970 Recession. The declarations by Democrat leaders on the economic situation and the request by the Richard Nixon administration to increase the debt ceiling caused the DJIA to decrease (-3.14%) on May 25, 1970. However, the rumors of a change in economic policy, and the meeting between President Richard Nixon and finance and business representatives are associated with a rise in the DJIA (+5.08%) on May 27, 1970. This increase is confirmed by the declarations of the Fed's Chairman Arthur Burns on the economic situation (+3.16%) on May 28, 1970.

1975-1980 Expansion. The rise of Wall Street (+4.46%) on November 1, 1978, can be explained by the announcement of President Jimmy Carter's program to support

the sagging dollar, including the rise of interest rates (from 8.5% to 9.5% for the prime rate), the buying of threatened US currency with $30 billion in foreign currency, and an increase in gold sales.

1982-1990 Expansion. The publication of the last economic statistics with a rise of the major leading indicators (0.6% in October) causes the rise of the DJIA (+3.63%) on November 30, 1982. The pessimistic economic and inflation forecasts can explain the severe fall of the DJIA (-6.85%) on January 8, 1988. In this context, the Brady Commission report, required by President Ronald Reagan as part of the stock market reform following the October stock market collapse, was poorly received by investors. The DJIA fell by 2.33% on April 14, 1988, following the announcement of the increase in the US trade deficit in February ($13.8 billion).

1991-2001 Expansion. The stagnation of US economic activity coincides with the fall of the DJIA (-3.93%) on November 27, 1991. The announcement of a new decrease in retail sales along with stagnant industrial production in October confirmed that the economic revival would not be imminent. The DJIA rebounded spectacularly, by 4.71% on October 28, 1997, following President Bill Clinton's affirmation that he was confiednt in the health of the US economic. The announcement of a higher than expected rise in consumption prices prompted the fall of the DJIA (-5.66%) on April 13, 2000. The drop in the DJIA (-4.10%) on March 12, 2001, is due to two events: first, US economic statistics showing that the US economy slowed, and second, the fall in growth shares, especially Intel, Yahoo and Cisco, which announced lower than expected results. On March 15, 2000, following the warning to investors by Fed Chairman Alan Greenspan to value new technology companies too quickly and too high compared with those of the traditional economy, the DJIA increases by 4.93% due to renewed interest by investors in traditional stocks rather than technology stocks.

2001–2007 Expansion. The DJIA rises sharply (+5.42%) on July 29, 2002, due to the announcement of positive results by firms and recent falls in share prices, implying a financial upswing.

4.2.6 The September 11 Terrorist Attacks

The terrorist attacks in the US on September 11, 2001 affected stock markets around the world. The US markets remained closed for four days, whereas the European markets decided to remain open but felt the consequences of the terrorist attacks. The DJIA fell by "only" 7.13% when the US markets reopened on September 17, 2001. Indeed, the US stock markets were supported by the interventions of the central banks, in particular the Fed[19] and the European Central Bank, which lowered their interest rates, and by technical provisions on the repurchases of shares by companies. Such provisions are generally used to prevent a stock market crash. Moreover, the authorities intervened to dissuade the banks and trust companies from lending their securities to speculative funds, to discourage short selling transactions, which amplify market plunges.

Wall Street experienced a period of turmoil following the September 11 attacks due to the US military response. The fall of the DJIA (-4.37%) on September 20, 2001, was caused by anxieties concerning the types of military counterattack against the Taliban system in Afghanistan and terrorist organizations, and also the fears of US recession from the last economic forecasts. On the contrary, the beginning of military action on September 24, 2001, against the Taliban system in Afghanistan appeased the US stock markets, spurring a rise of 4.47% in the DJIA.

4.2.7 Politico-economic Conflicts

On March 18, 1938, the Mexican President Cárdenas nationalized all foreign-owned oil properties within its borders. He sided with the oil workers in the conflict between them and their American and British employers. The workmen demanded higher

[19]The Fed took steps to provide a high level of liquidity ($100 billion) through the US banking and financial sector. The Fed policy thus calmed and stabilized the economy (Chen and Siems, 2004). On September 14, the Fed encouraged the banks to grant appropriations to the solvent borrowers and to modify the initial terms of the credit terms and other transactions, in particular lengthening the duration of repayment and reorganization of debt. See Chesney et al. (2011) for a discussion of the impact of terrorism on financial markets.

wages and welfare benefits. The US government decided that it would not protest if the Mexican government compensated the US oil companies equitably, but it doubted the capacity of the Mexican government to pay the companies.[20] This politico-economic conflict prompted a decrease in the DJIA on March 25 and 29, 1938 (-5.30% and -4.97%, respectively).

The Cuban missile crisis can explain the rise of the DJIA (+3.34%) on October 24, 1962, because Soviet President Khrushchev promised not ta make any rash decisions concerning the crisis, and proposed a US-Soviet summit. The crisis began on October 16, 1962 when US reconnaissance planes discovered Soviet nuclear missile installations on Cuba. This led to a twelve day stand-off between US President John F. Kennedy and Soviet premier Nikita Khrushchev. The crisis ended on October 28, 1962, when the Soviets announced that the installations would be dismantled.

4.2.8 Bankruptcy and Investigation

The major banks' rejection of the plan to buy out United Airlines can explain the considerable losses in the DJIA (-6.91%) on October 13, 1989. The crash was apparently caused by a reaction to a news story abouot the break-down of a $6.75 billion leveraged buyout deal for United Continental Holdings (UAL) Corporation, the parent company of United Airlines.

The strong fall of the DJIA (-4.64%) on July 19, 2002, can be explained by several negative announcements: (i) disappointing forecasts from Sun Microsystems and Microsoft; (ii) the opening of an investigation by the American pharmaceutical authorities against the pharmaceutical company Johnson & Johnson; and (iii) the possible bankruptcy filing of the telecommunications firm WorldCom.[21]

[20] This nationalization plan caused the rupture of diplomatic relations with Great Britain until 1942. The US orchestrated the world boycott of the new company Petróleos Mexicanos (Pemex) for thirty years.

[21] Worldcom filed for Chapter 11 bankruptcy on July 21, 2002, one of the largest bankruptcy filings in US history ($103.9 billion in assets), surpassing Enron ($63.1 billion in assets) (see Akhigbe, Martin and Whyte, 2005). The largest bankruptcies are Lehman Brothers ($639.0 billion in assets) and Washington Mutual ($327.9 billion in assets) which filed for Chapter 11 bankruptcy protection on September 15 and

The strong rise of the DJIA (+6.35%) on July 24, 2002, can be explained by (i) the announcement of a reform of the accounting rules by the American administration to reassure the markets, in particular by creating an accounting oversight committee of companies and audit firms; and (ii) the opening of investigations by the Securities and Exchange Commission (SEC) against AOL Time Warner (leading media group in the world), Adelphia Communications (the sixth largest American cable-television company, which filed for bankruptcy and whose leaders were arrested) and a dozen investment banks, due to doubt over the veracity of these firms' accounts.

4.2.9 Regulation

First Glass-Steagall Act. In 1932, economic conditions have deteriorated worldwide and many people sought to protect themselves by purchasing and hoarding gold. The result of this behavior is a contraction of credit. Therefore, an effort was made to expand credit under the leadership of Democrat Senator Carter Glass and Democrat Representative Henry Steagall. This decision caused a rise of the DJIA on February 11 (+9.47%) and 13 (+9.19%), 1932. The result of their collaboration is known as first Glass-Steagall Act, which accomplished the following: (i) liberalized the Federal Reserve rules regarding the acceptability of commercial paper for rediscount purpose, and (ii) making more than $750 billion of the nation's gold reserve available for loans to credit-worthy businesses and industries.

National Banking Holiday. After an eleven-day interruption due to National Banking holiday,[22] the NYSE re-opened on March 15, 1933, with a strong rise (+15.34% for the DJIA). It seems that the measures adopted by President Franklin Roosevelt to solve the banking crisis and to balance the budget reassured investors, especially the Emergency Banking Act or the Glass-Steagall Act[23] (law to banks from engaging

26, 2008, respectively.

[22]On March 6, 1933, the President Franklin Roosevelt imposes the closing of all the American banks for four days (banking holiday) which necessarily implies the closing the stock markets. For a discussion of the National banking holiday see Wigmore (1987), Schwert (1989b) and Butkiewicz (1999), *inter alia*.

[23]The Glass-Steagall Act, also called Banking Act of 1933, instituted incompatibility between trading by deposit and investment banks; created the federal system of bank deposit insurance (the Federal

in speculation). These measures placed the market under governmental control, created restrictions on advances that brokers could receive and obliged brokers and the members of Stock Exchange to file daily reports on bank loans.[24]

The National Industrial Recovery Act. The new warning by the National Recovery Administration[25] against speculative excesses led to large sale orders, worsened by the strong recovery of the dollar and the collapse of the principal raw materials, and prompting a plunge in the DJIA (-7.84%) on July 21, 1933.

4.2.10 Miscellaneous

The rise of the DJIA (+9.08%) on May 6, 1932, can be explained by the insurance merger between the Consolidated Indemnity and Insurance Company and the Transportation Indemnity Company. The restoration of the gold embargo, implied a renunciation of the gold standard, which explains a rise in the DJIA (+9.03%) on April 19, 1933.

5 Volatility changes in the DJIA

We find that some negative and positive high returns experienced by the DJIA are not identified as outliers, namely as extraordinary (rare) movements, due to the very high volatility of some periods (see, e.g., Officer, 1973; Schwert, 1989a). This can be explained by differing consequences and perceptions of the investors when the market is experiencing high volatility rather than low volatility or stability. Therefore, we

Deposit Insurance Corporation, FDIC); introduced the leveling off of the interest rates on bank deposits (Regulation Q). The Regulation was repealed in 1980 by the Depository Institutions Deregulation and Monetary Control Act, and the Glass-Steagall Act was abrogated on November 12, 1999, by the Financial Services Modernization Act (or Gramm-Leach-Bliley Act). See Moshirian (2011) for a discussion of regulations and market development.

[24]Thereafter, the Securities and Exchange Commission (SEC) – the federal organization of regulation and control of the financial markets – was created on June 6, 1934.

[25]The National Industrial Recovery Act (NIRA) came into force on June 16, 1933, to support prices and wages. It established an organization of regulation, the National Recovery Administration (NRA). The Supreme Court annulled the NIRA on May 27, 1935.

use an appropriate methodology to identify breakpoints and sudden shifts in volatility of the DJIA. A relatively recent approach to test for volatility shifts is the iterative cumulative sums of squares (ICSS) algorithm proposed by Inclán and Tiao (1994) and improves by Sansó et al. (2004). This algorithm allows the detection of multiple breakpoints in variance and has been used extensively to identify changes in volatility of financial time series (Fernandez, 2006; Hammoumdeh and Li, 2008; Kasman, 2009, among others).[26] Nevertheless, Rodrigues and Rubia (2011) show that the asymptotic distribution of the ICSS test statistics varies under additive outliers. The critical values from this distribution generally prove inadequate for the test, which finds too many breaks.[27] Therefore, using the outlier-adjusted DJIA return series, we apply the modified ICSS algorithm to detect sudden changes in volatility.

5.1 Sudden change detection

The most popular statistical methods specifically designed to detect breaks in volatility are CUSUM-type tests. As underlined by Rodrigues and Rubia (2011), the ability of the CUSUM tests to identify structural changes depends of the underlying assumptions. Financial data display a time varying volatility pattern, known as volatility clustering. Andreou and Ghysels (2002) illustrate the pervasive effect of persistent volatility on CUSUM-type tests experimentally. Their results indicate that the Kokoszka and Leipus (2000) test is robust to conditional heteroscedasticity. Sansó et al. (2004) propose a more general test than that of Kokoszka and Leipus (2000) based on the iterative cumulative sum of squares (ICSS) algorithm developed by Inclán and Tiao (1994).

Let $e_{i,t} = 100 \times \log(P_{i,t}/P_{i,t-1})$, where $P_{i,t}$ is the price of the index i at the time t, so that e_t is the percent return of the index i from period $t-1$ to t. $\{e_t\}$ is then assumed to be a series of independent observations from a normal distribution with zero mean

[26] Haugen et al. (1991) used the methodology developed by Wichern et al. (1976) for identifying variance change points in the DJIA over the period 1897–1988.

[27] Further, Inclán and Tiao (1994) advised that "*it is advisable to complement the search for variance changes with a procedure for outlier detection*".

and unconditional variance σ_t^2 for $t = 1, \ldots, T$. Assume that the variance within each interval is denoted by σ_j^2, $j = 0, 1, \ldots, N_T$, where N_T is the total number of variance changes and $1 < \kappa_1 < \kappa_2 < \cdots < \kappa_{N_T} < T$ are the set of breakpoints. Then the variances over the N_T intervals are defined as

$$\sigma_t^2 = \begin{cases} \sigma_0^2, & 1 < t < \kappa_1 \\ \sigma_1^2, & \kappa_1 < t < \kappa_2 \\ \cdots & \\ \sigma_{N_T}^2, & \kappa_{N_T} < t < T \end{cases}$$

The cumulative sum of squares is used to estimate the number of variance changes and to detect the point in time of each variance shift. The cumulative sum of the squared observations from the beginning of the series to the kth point in time is expressed as $C_k = \sum_{t=1}^{k} e_t^2$ for $k = 1, \ldots, T$. To test the null hypothesis of constant unconditional variance, the Inclán–Tiao statistic is given by:

$$IT = \sup_k |(T/2)^{0.5} D_k| \tag{7}$$

where $D_k = \left(\frac{C_k}{C_T}\right) - \left(\frac{k}{T}\right)$, with C_T is the sum of the squared residuals from the whole sample period. The value of k that maximizes $|(T/2)^{0.5} D_k|$ is the estimate of the break date. The ICSS algorithm systematically looks for breakpoints along the sample. If there are no variance shifts over the whole sample period, D_k will oscillate around zero. Otherwise, if there are one or more variance shifts, D_k will deviate from zero. The asymptotic distribution of the IT statistic is given by $sup_r |W^*(r)|$, where $W^*(r) = W(r) - rW(1)$ is a Brownian bridge and $W(r)$ is standard Brownian motion. Finite-sample critical values can be generated by simulation.

The IT statistic is designed for i.i.d. processes, which is a very strong assumption for financial data, in which there is evidence of conditional heteroscedasticity. Sansó et al. (2004) show that the size distortions are important for heteroscedastic conditional variance processes from Monte Carlo simulations. Their results thus invalidate the practical use of this test for financial time series. To overcome this problem, Sansó et al. (2004) propose a new test that explicitly consider the fourth moment properties

of the disturbances and the conditional heteroscedasticity.[28] They propose a non-parametric adjustment to the IT statistic that allows e_t to obey a wide class of dependent processes under the null hypothesis. Consistent with Sansó et al. (2004), we use a non-parametric adjustment based on the Bartlett kernel, and the adjusted statistic[29] is given by:

$$AIT = \sup_k |T^{-0.5} G_k| \tag{8}$$

where $G_k = \hat{\lambda}^{-0.5}\left[C_k - \left(\frac{k}{T}\right)C_T\right]$, $\hat{\lambda} = \hat{\gamma}_0 + 2\sum_{l=1}^{m}\left[1 - l(m+1)^{-1}\right]\hat{\gamma}_l$, $\hat{\gamma}_l = T^{-1}\sum_{t=l+1}^{T}(e_t^2 - \hat{\sigma}^2)(e_{t-l}^2 - \hat{\sigma}^2)$, $\hat{\sigma}^2 = T^{-1}C_T$, and the lag truncation parameter m is selected using the procedure in Newey and West (1994). Under general conditions, the asymptotic distribution of AIT statistic is also given by $sup_r|W^*(r)|$, and finite-sample critical values can be generated by simulation.

5.2 Sudden changes in the DJIA

Table 6 displays the time periods of a shift in DJIA volatility, as detected by the modified ICSS algorithm, and descriptive statistics for the return series on sub-periods identified from volatility shifts. The modified ICSS algorithm finds changes in volatility, especially episodes of high volatility occurring in 1929-1934, 1937-1938 and 2008-2010. All the returns in the sub-periods exhibit excess skewness, excess kurtosis and conditional heteroscedasticity. Episodes of higher volatility occur in 1929-1934 and 1937-1938, with a standard deviation of 0.020, present at least twice the volatility as the other periods, as found by Schwert (1989b) (see also Officer, 1973; Schwert, 1989a, 1998).[30] Voth (2003) shows that this high volatility can be explained by the

[28] Bacmann and Dubois (2002) show that one way to circumvent this problem is by filtering the return series by a GARCH (1,1) model, and applying the ICSS algorithm developed by Inclán and Tiao (1994) to the standardized residuals obtained from the estimation. Fernandez (2006) proposes an alternative approach to testing for variance homogeneity based on wavelet analysis.

[29] This adjusted statistic is equivalent to the non-parametric test proposed by Kokoszka and Leipus (2000).

[30] Schwert (1989b) finds that the sub-periods 1929-1934 and 1937-1938 exhibit high volatility from a switching-regime Markov model (with two regimes) for a monthly constructed stock-return series based

political uncertainty. Further, we demonstrate that the 2008–2010 period is associated with very high levels of volatility (standard deviation of 0.016) but we cannot say that the DJIA returned to a period of "normal" (or less high) volatility because it is difficult to detect volatility changes at the end of a sample. The 2008–2010 period appears thus to be relatively *de facto* short-lived (a few years). More data are necessary to determine a volatility change at the end of the sample, and thus characterize this period as short-lived or not, and compare it to the prolonged periods (many years) of high volatility between 1929 and 1934.[31]

6 Conclusion

This study examined the kinds of events that cause large shocks, considered as black swans or rare events, in the volatility of the DJIA index between October 2, 1928 and December 31, 2010. More precisely, from intervention analysis based on a conditional heteroscedasticity model, we determined when these (positive and negative) large changes in volatility of daily returns occur during this period. We also tried to associate the date of each outlier with a specific (economic, political or financial) event that occurred near that date, and many of them seem to be associated with the same event patterns. We found that the large volatility shocks are principally due to the major financial crashes, the US elections, wars, monetary policies during the recessions, macroeconomic news and declarations on the economic situation, terrorist attacks, politico-economic conflicts, bankruptcy, and regulation. This finding suggests that these large shocks should be thus taken into account in modelling volatility of returns along with in macro-finance models.

We also showed that some shocks were not identified as extraordinary movements due to their occurring during high volatility episodes, especially the 1929-1934, 1937-1938

largely on data from the Center for Research in Security Prices (CRSP) for the 1834–1987 period.

[31] Schwert (2011) uses monthly returns of a daily index of New York Stock Exchange-listed stocks from 1885–2010, principally based on data from the CRSP and the S&P 500. He finds contrast between the period following the 2008 financial crisis and the Great Depression in terms of standard deviation.

and 2008-2010 periods, identified from the ICSS algorithm. We cannot conclude that the 2008-2010 period which is associated with very high levels of volatility is short-lived (a few years) in contrast to the prolonged periods (many years) of high volatility between 1929 and 1934, because more data are necessary to determine a volatility change at the end of the sample. This question will be the aim of further research. This study focuses on the events that cause large shocks in the volatility of US stock market. It will be interesting to study others stock markets and/or financial markets, such as bond and foreign exchange rate markets, to compare the market's reactions to such events.

Figure 1: Daily returns of DJIA – 1928-2010

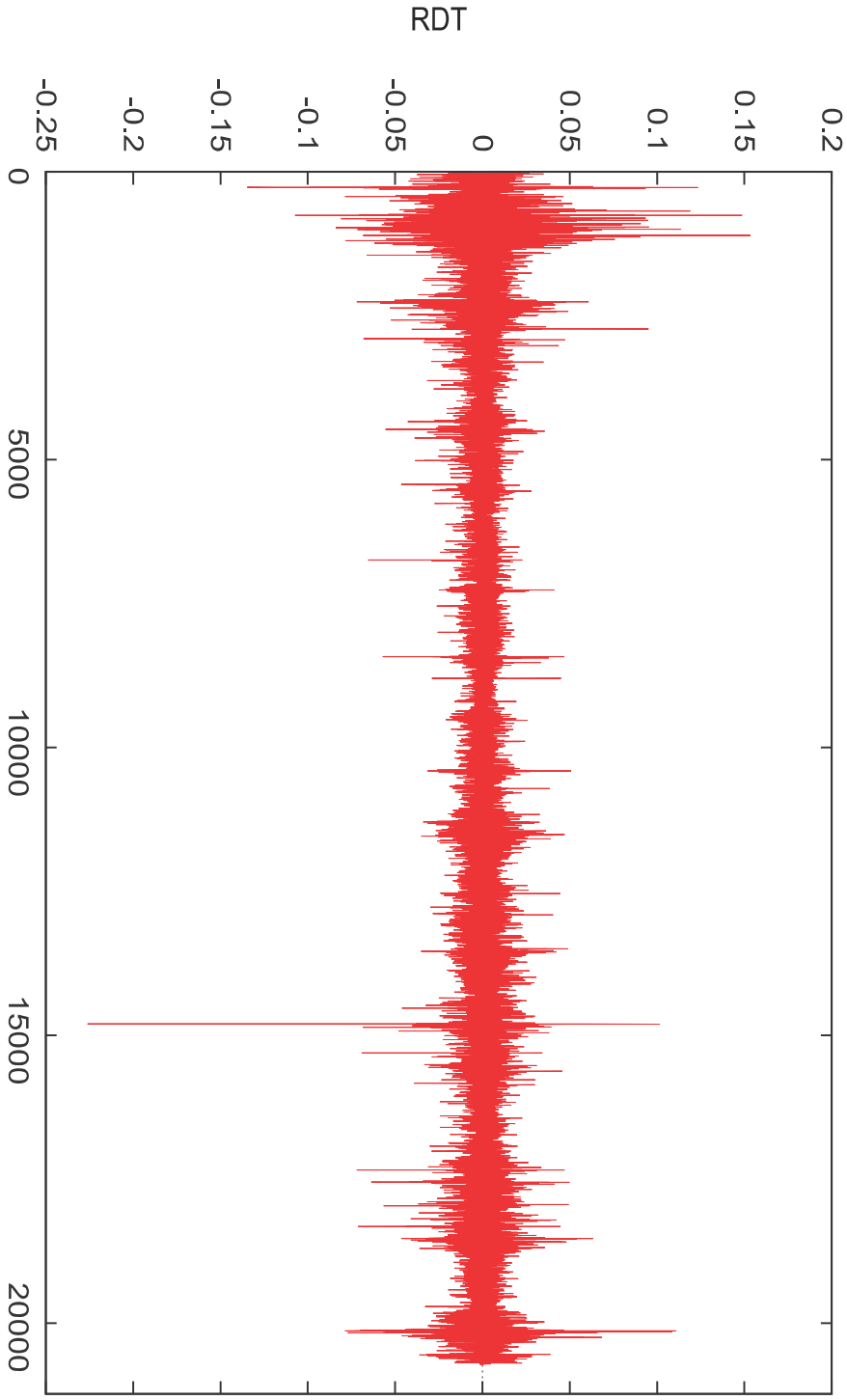

Table 1: Summary statistics of the DJIA: 1928–2010.

Series	Mean (%)	St. dev.	Min.	Max.	Skewness	Excess Kurtosis	LM(10)
Non-adjusted	0.0255	0.012	-0.226	0.153	-0.163*	21.06*	2590.9*
Outlier-adjusted	0.0248	0.010	-0.058	0.053	-0.164*	3.47*	4697.5*

Notes: * and ** mean significant at 5% and 10% level, respectively.

Table 2: Large shocks detected in the DJIA: 1928–1938.

Date	Type	size	t-stat	Point Change	Percent Change	Events
10/28/1929	IO	-17.59	-17.87	-40.58	-13.47	Black Monday
10/29/1929	IO	-14.94	-15.38	-30.57	-11.73	Black Tuesday
10/30/1929	IO	17.46	18.59	28.40	12.34	Massive purchases of stocks
11/06/1929	IO	-12.60	-13.95	-25.55	-9.92	Accumulation of selling orders
11/14/1929	IO	9.75	11.48	18.59	9.36	Possible reduction of income taxes
06/22/1931	AO	13.45	15.43	15.51	11.90	Hoover debt moratorium proposal
10/05/1931	AO	-10.35	-12.78	-10.40	-10.74	Fall of European stock exchanges
10/06/1931	AO	20.18	21.17	12.86	14.87	Noise of constitution of banking syndicate
12/18/1931	AO	7.61	10.77	6.90	9.35	Constitution of support funds
02/11/1932	IO	8.17	10.88	6.80	9.47	First Glass-Steagall Act
02/13/1932	IO	8.11	10.79	7.22	9.19	First Glass-Steagall Act
05/06/1932	AO	7.52	10.63	4.91	9.08	Insurance merger
08/03/1932	IO	8.21	11.00	5.06	9.52	
08/12/1932	AO	-7.91	-10.61	-5.79	-8.40	Downward readjustment
09/21/1932	AO	11.62	13.92	7.67	11.37	Roosevelt's declarations
10/05/1932	IO	-4.91	-10.26	-5.09	-7.15	Fall in grain prices
03/15/1933	AO	20.18	28.20	8.26	15.34	End of National banking holiday and Glass-Steagall Act
04/19/1933	IO	7.47	12.79	5.66	9.03	Restoration of the gold embargo
06/19/1933	AO	5.12	10.72	6.77	7.59	Roosevelt's opposition to monetary project
07/21/1933	AO	-5.26	-10.75	-7.55	-7.84	Warning against speculation
10/05/1937	IO	-2.51	-10.23	-8.11	-5.33	Roosevelt's declaration on a possible international conflict
10/18/1937	IO	-4.78	-14.06	-9.75	-7.20	Bad economic statistics
10/20/1937	IO	3.56	13.55	7.71	6.08	Possible readjustment of the tariffs of goods
11/19/1937	IO	-3.02	-11.90	-7.35	-5.86	Bad economic statistics
03/25/1938	IO	-2.49	-10.21	-6.07	-5.30	Nationalization of Mexican oil
03/29/1938	AO	-2.38	-10.12	-5.37	-4.97	Nationalization of Mexican oil
01/23/1939	AO	-2.65	-12.34	-7.79	-5.22	Spanish Civil War

Notes: The t-statistics are compared to the critical value equal to 10 computed by Franses et van Dijk (2000b). The size values are multiplied by 10^3.

Table 3: Large shocks detected in the DJIA: 1939–1969.

Date	Type	size	t-stat	Point Change	Percent Change	Events
09/05/1939	AO	8.78	24.94	12.87	9.52	European conflict
09/18/1939	IO	-1.53	-10.67	-6.25	-4.06	Invasion of Poland by Soviet Union
05/13/1940	IO	-2.39	-11.53	-7.14	-4.93	World War II
05/14/1940	IO	-4.44	-17.19	-9.36	-6.80	World War II
05/17/1940	AO	-2.66	-12.65	-6.23	-4.78	World War II
05/21/1940	AO	-4.47	-19.01	-8.30	-6.78	World War II
06/12/1940	AO	2.06	13.03	5.49	4.73	Roosevelt's declaration on the war
11/07/1940	AO	1.80	13.08	5.77	4.37	Roosevelt's reelection
04/09/1943	AO	-1.00	-11.19	-4.30	-3.17	Roosevelt's anti-inflation order
02/25/1946	IO	-1.77	-14.16	-8.39	-4.29	Threat of inflation
09/03/1946	IO	-3.05	-19.39	-10.51	-5.56	Labor unrest in maritime and trucking industries
09/09/1946	AO	-2.00	-15.32	-7.93	-4.41	Labor unrest in maritime and trucking industries
10/15/1946	AO	1.10	11.20	6.08	3.58	Deregulation of meat prices
11/06/1946	AO	-0.92	-10.57	-5.52	-3.17	Republican victories in Congress
12/09/1946	AO	0.90	10.60	5.37	3.15	Coal strike ends
04/14/1947	AO	-1.49	-12.33	-6.74	-3.89	Worsening of economic situation
11/03/1948	IO	-1.48	-14.80	-7.30	-3.85	Truman defeats Dewey
11/05/1948	IO	-1.24	-12.41	-6.16	-3.34	Fear of reestablishment of earning taxes
06/26/1950	IO	-2.18	-18.75	-10.44	-4.65	Outbreak of Korean War
06/29/1950	IO	-1.52	-14.60	-7.96	-3.71	North Korea tanks entered Seoul; fear of long war
09/26/1955	IO	-4.31	-41.45	-31.89	-6.54	Eisenhower's heart attack
09/27/1955	IO	0.86	10.81	10.37	2.28	Good news of the Eisenhower's health
10/10/1955	IO	-0.85	-10.72	-13.27	-2.92	Bad news of the Eisenhower's health
10/23/1957	AO	1.54	18.20	17.34	4.13	Eisenhower's declarations on the economic situation
05/28/1962	IO	-3.19	-32.18	-34.95	-5.71	Kennedy forces rollback of steel price hike
05/29/1962	IO	2.46	26.15	27.03	4.69	Dillon's declarations on the economic situation
06/04/1962	IO	-1.28	-17.39	-17.37	-2.84	Bad economic statistics
06/28/1962	AO	1.27	15.54	20.37	3.79	Possible intention to diminish income taxes
10/24/1962	AO	0.98	12.63	18.62	3.34	Cuban missile crisis
11/22/1963	AO	-0.85	-11.38	-21.16	-2.89	President Kennedy's assassination
11/26/1963	AO	1.89	22.59	32.03	4.50	Arrestation of the Kennedy's assassin

Notes: The t-statistics are compared to the critical value equal to 10 computed by Franses et van Dijk (2000b). The size values are multiplied by 10^3.

Table 4: Large shocks detected in the DJIA: 1970–1989.

Date	Type	size	t-stat	Point Change	Percent Change	Events
05/25/1970	IO	-0.83	-11.02	-20.81	-3.14	Democrats's declarations on the economic situation
05/27/1970	AO	2.22	21.37	32.04	5.08	Rumors of change in economic policy
05/28/1970	IO	0.85	11.32	20.95	3.16	Burns's declarations on the economic situation
08/16/1971	AO	1.39	11.17	32.93	3.85	Nixon anti-inflationary program
07/12/1974	AO	1.37	11.04	27.61	3.64	Lower inflation
10/07/1974	IO	1.40	10.30	23.00	3.94	Expectations of strong anti-inflationary measures
10/09/1974	IO	1.91	13.28	28.39	4.71	Ford proposals to reduce inflation and interest rate
10/29/1974	AO	1.42	10.71	25.50	4.02	Fall in short-term interest rates; lower oil prices
01/27/1975	AO	1.39	10.66	26.05	3.91	Fall in short-term interest rates
11/01/1978	AO	1.86	12.69	35.34	4.46	Carter program to support dollar
04/22/1980	AO	1.55	11.57	30.72	4.05	Fall in short-term interest rates
08/17/1982	IO	2.31	14.09	38.81	4.90	Crisis of the debt; fall in interest rate
08/20/1982	IO	1.36	11.05	30.72	3.66	Fall in interest rate; cut in prime rates
10/06/1982	IO	1.67	12.01	37.07	4.09	Expectation of further decline of interest rates
10/25/1982	IO	-1.15	-10.09	-36.33	-3.52	Fed's failure to cut discount rates
11/03/1982	AO	1.61	11.90	43.41	4.25	Relief over small Democratic victories in House
11/30/1982	IO	1.58	11.01	36.43	3.63	Good economic statistics
09/11/1986	AO	-2.10	-11.54	-86.61	-4.61	Fear of fall in interest rate and inflation
10/16/1987	IO	-1.97	-11.58	-108.36	-4.60	Higher trade deficit; fear of higher interest rate
10/19/1987	AO	-50.29	-152.40	-507.99	-22.61	Fear of a new decline of dollar
10/20/1987	IO	3.07	15.62	102.27	5.88	Fall in bank's prime lending rate
10/21/1987	IO	9.79	37.12	186.84	10.15	Fall in interest rates
10/22/1987	IO	-1.74	-10.87	-77.42	-3.82	Tensions in the Persian golf; fear of lower stock prices
10/26/1987	IO	-6.45	-27.92	-156.83	-8.04	Reopening of Hong Kong stock market; fear of budget deficit
10/29/1987	IO	2.58	14.01	91.51	4.96	Dollar stabilization; fall of interest rates
11/30/1987	IO	-1.66	-10.94	-76.93	-4.03	Fear of dollar fall
01/08/1988	AO	-4.54	-22.35	-140.58	-6.85	Pessimistic forecasts on economy and inflation
04/14/1988	AO	-2.27	-12.22	-101.46	-2.33	Increase of trade deficit
10/13/1989	AO	-4.78	-27.71	-190.58	-6.91	Rejection of repurchase plan of United Airlines

Notes: The t-statistics are compared to the critical value equal to 10 computed by Franses et van Dijk (2000b). The size values are multiplied by 10^3.

Table 5: Large shocks detected in the DJIA: 1990–2010.

Date	Type	size	t-stat	Point Change	Percent Change	Events
01/17/1991	AO	1.94	13.69	114.60	4.57	Operation Desert Storm
11/15/1991	AO	-1.54	-11.41	-120.31	-3.93	Bad economic statistics; fear of economic stagnation
10/27/1997	AO	-5.14	-24.74	-554.26	-7.18	Asian crisis
10/28/1997	AO	2.15	13.47	337.17	4.71	Clinton's declaration on the economic health
08/27/1998	IO	-1.69	-10.97	-357.36	-4.19	Asian and Russian crisis; fear of contagion in emerging markets
08/31/1998	IO	-3.89	-19.39	-512.61	-6.37	Deterioration of Asian and Russian crises
09/01/1998	IO	1.68	10.70	288.36	3.83	Financial rebound
09/08/1998	IO	2.34	12.02	380.53	4.98	Possible relaxation of monetary policy
10/15/1998	AO	1.56	10.84	330.58	4.15	Unexpected reduction of interest rates
03/16/2000	AO	2.13	12.34	499.19	4.93	Renewed interest in traditional shares
04/14/2000	AO	-3.06	-16.23	-617.78	-5.66	Rise in consumption prices
03/12/2001	IO	-1.61	-10.01	-436.37	-4.10	Bad economic statistics; slowing down of economy
09/17/2001	IO	-5.06	-22.47	-684.81	-7.13	The September 11 terrorist attacks
09/20/2001	IO	-2.16	-11.45	-382.92	-4.37	Anxiety on military actions against Taliban
09/24/2001	IO	2.14	12.43	368.05	4.47	Beginning of military actions against Taliban
07/19/2002	IO	-1.97	-10.17	-390.23	-4.64	Fear of WorldCom bankruptcy
07/24/2002	AO	3.46	15.43	488.95	6.35	Investigations against AOL Time Warner
07/29/2002	AO	2.46	11.69	447.49	5.42	Good firm results
02/27/2007	AO	2.02	10.91	-416.02	-3.29	Fall of Shanghai Stock Exchange; fear of recession
09/29/2008	IO	-4.37	-13.66	-777.68	-6.98	Rejection of Paulson's bailout plan
10/09/2008	IO	-4.90	-14.90	-678.91	-7.33	Contagion of the crisis in Europe
10/13/2008	IO	10.67	23.51	936.42	11.08	US and European government's interventions
10/15/2008	IO	-5.90	-16.25	-733.08	-7.87	Bad economic statistics; fear of recession
10/22/2008	IO	-3.74	-12.40	-514.45	-5.70	Bad firm results; fear of severe and long recession
10/28/2008	AO	10.21	26.50	889.35	10.88	Purchase opportunities
11/13/2008	IO	3.47	11.63	552.59	6.67	Issue of Treasury bonds
11/20/2008	IO	-3.11	-10.64	-427.47	-5.07	Bad economic statistics; fear of deflation
11/21/2008	IO	3.40	12.03	494.13	6.54	Bailout plan for Citigroup
12/01/2008	AO	-5.03	-14.48	-679.95	-7.70	Bad economic statistics; fear of severe recession
03/10/2009	AO	2.81	10.27	379.44	5.80	Earnings for Citigroup
03/23/2009	AO	4.04	12.93	497.48	6.84	Geithner's bailout plan

Notes: The t-statistics are compared to the critical value equal to 10 computed by Franses et van Dijk (2000b). The size values are multiplied by 10^3.

Table 6: Sudden changes in DJIA volatility and summary statistics on sub-periods.

Dates of change breaks	Mean (%)	St. dev.	Min.	Max.	Skewness	Excess Kurtosis	LM(10)
10/02/1928–10/16/1934	-0.030	0.025	-0.135	0.153	-0.354*	4.30*	157.1*
10/17/1934–08/25/1937	0.095	0.010	-0.037	0.029	-0.446*	1.13*	9.9
08/26/1937–10/05/1938	-0.052	0.021	-0.072	0.061	-0.217*	0.53*	16.3**
10/06/1938–07/08/1942	-0.028	0.011	-0.068	0.095	-0.031*	10.73*	48.9*
07/09/1942–02/06/1973	0.031	0.007	-0.065	0.051	-0.418*	5.69*	572.1*
02/07/1973–10/13/1992	0.029	0.011	-0.226	0.102	-1.839*	46.84*	316.3*
10/14/1992–12/15/1995	0.062	0.006	-0.025	0.023	-0.269*	1.60*	18.8*
12/18/1995–04/03/2003	0.033	0.012	-0.072	0.064	-0.133*	3.03*	156.7*
04/04/2003–07/11/2007	0.048	0.007	-0.033	0.022	-0.155*	0.88*	34.1*
07/12/2007–12/31/2010	-0.004	0.016	-0.079	0.111	0.291*	7.14*	222.7*

Notes: * and ** mean significant at 5% and 10% level, respectively.

Table 7: Largest daily percentage changes and losses on the DJIA, October 1928 – December 2010.

	Largest changes		Largest losses	
Rank	Date	% change	Date	% change
1	19/10/1987	-22.61	19/10/1987	-22.61
2	15/03/1933	+15.34	28/10/1929	-12.82
3	06/10/1931	+14.87	29/10/1929	-11.73
4	28/10/1929	-12.82	10/05/1931	-10.74
5	31/10/1929	+12.34	06/11/1929	-9.92
6	29/10/1929	-11.73	12/08/1932	-8.40
7	21/09/1932	+11.36	26/10/1987	-8.04
8	13/10/2008	+11.08	15/10/2008	-7.87
9	28/10/2008	+10.88	21/07/1933	-7.84
10	10/05/1931	-10.74	01/12/2008	-7.70
10	21/10/1987	+10.15	09/10/2008	-7.33
11	06/11/1929	-9.92	18/10/1937	-7.20
12	03/08/1932	+9.52	27/10/1997	-7.18
13	11/02/1932	+9.47	05/10/1932	-7.15
14	14/11/1929	+9.36	17/09/2001	-7.13
15	18/12/1931	+9.35	24/09/1931	-7.07
16	13/02/1932	+9.19	20/07/1933	-7.07
17	06/05/1932	+9.08	29/09/2008	-6.98
18	19/04/1933	+9.03	13/10/1989	-6.91
19	08/10/1931	+8.70	08/01/1988	-6.85

References

[1] Akgiray V. (1989). Conditional heteroscedasticity in time series of stock returns: Evidence and forecasts. Journal of Business, 62, 55-80.

[2] Akhigbe A., Martin A.D. and Whyte A.M. (2005). Contagion effects of the world's largest bankruptcy: The case of WorldCom. The Quaterly Review of Economics and Finance, 45, 48-64.

[3] Amihud Y. and Wohl A. (2004). Political news and stock prices: The case of the Saddam Hussein contracts. Journal of Banking and Finance, 28, 1185-1200.

[4] Bacmann J.F. and Dubois M. (2002). Volatility in emerging stock markets revisited. European Financial Management Association, London Meeting, 26-29 June 2002.

[5] Balke N.S. and Fomby T.B. (1994). Large shocks, small shocks, and economic fluctuations: Outliers in macroeconomic time series. Journal of Applied Econometrics, 9, 181-200.

[6] Barro R.J. (2006). Rare disasters and asset markets in the Twentieth Century. Quarterly Journal of Economics, 121, 823-866.

[7] Barro R.J. and Ursúa J.F. (2009). Stock-market crashes and depressions. Working Paper No 1470, NBER.

[8] Bartram S.M. and Bodnar G.M. (2009). No place to hide: The global crisis in equity markets in 2008/2009. Journal of International Money and Finance, 28, 1246-1292.

[9] Berkman H., Jacobsen B. and Lee J.B. (2011). Time-varying rare disaster risk and stock returns. Journal of Financial Economics, 101, 313-332.

[10] Bialkowski J., Gottschalk K. and Wisniewski T.P. (2008). Stock market volatility around national elections. Journal of Banking and Finance, 3, 1941-1953.

[11] Bierman H. (1998). The Causes of the 1929 Stock Market Crash. Greenwood Press, Westport.

[12] Birz G. and Lott J.R. (2011). The effect of macroeconomic news on stock returns: New evidence from newspaper coverage. Journal of Banking and Finance, forthcoming.

[13] Bloom N. (2009). The impact of uncertainty shocks. Econometrica, 77, 623-685.

[14] Bollerslev T. (1986). Generalized autoregressive conditional heteroskedasticity. Journal of Econometrics, 31, 307-327.

[15] Bollerslev T. (1987). A conditionally heteroskedastic time series model for speculative prices and rates of return. Review of Economic and Statistics, 69, 542-547.

[16] Bomfim A.N. (2003). Pre-announcement effects, news effects, and volatility: Monetary policy and the stock market. Journal of Banking and Finance, 27, 133-151.

[17] Box G.E.P. and Tiao G.C. (1975). Intervention analysis with applications to economic and environmental problems. Journal of the American Statistical Association, 70, 70-79.

[18] Butkiewicz J.L. (1999). The Reconstruction Finance Corporation, the gold standard, and the banking panic of 1933. Southern Economic Journal, 66, 271-293.

[19] Carlson M. (2006). A brief history of the 1987 stock market crash. Finance and Economics Discussion Series No 2007-13, Federal Reserve Board.

[20] Carnero M.A., Peña D. and Ruiz E. (2001). Outliers and conditional autoregressive heteroskedasticity in time series. Revista Estadistica, 53, 143-213.

[21] Carnero M.A., Peña D. and Ruiz E. (2006). Effects of outliers on the identification and estimation of the GARCH models. Journal of Time Series Analysis, 28, 471-497.

[22] Catalán B. and Trívez F.J. (2007). Forecasting volatility in GARCH models with additive outliers. Quantitative Finance, 7, 591-596.

[23] Chang I., Tiao G.C. and Chen C. (1988). Estimation of time series parameters in the presence of outliers. Technometrics, 30, 193-204.

[24] Charles A. (2008). Forecasting volatility with outliers in GARCH models. Journal of Forecasting, 27, 551-565.

[25] Charles A. and Darné O. (2005). Outliers and GARCH models in financial data. Economics Letters, 86, 347-352.

[26] Charles A. and Darné O. (2006). Large shocks and the September 11th terrorist attacks on international stock markets. Economic Modelling, 23, 683-698.

[27] Chen C. and Liu L.M. (1993). Joint estimation of model parameters and outlier effects in time series. Journal of the American Statistical Association, 88, 284-297.

[28] Chen A. and Siems T. (2004). The effects of terrorism on global capital markets. European Journal of Political Economy, 20, 349-366.

[29] Chesney M., Reshetar G. and Karaman M. (2011). The impact of terrorism on financial markets: An empirical study. Journal of Banking and Finance, 35, 253-267.

[30] Choudhry T. (2010). World War II events and the Dow Jones industrial index. Journal of Banking and Finance, 34, 1022-1031.

[31] Cutler D.M., Poterba J.M. and Summers L.H. (1989). What moves stock prices. Journal of Portfolio Management, 15, 4-12.

[32] Darné O. and Charles A. (2011). Large shocks in U.S. macroeconomic time series: 1860-1988. Cliometrica, 5, 79-100.

[33] Doornik J.A. and Ooms M. (2005). Outlier detection in GARCH models. Discussion Paper No 2005-092/4, Tinbergen Institute.

[34] Dow Jones & Co. (1996). The Dow Jones Averages 1885-1995. Pierce P.S. (ed.), Irwin, Homewood.

[35] Engle R.F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflations. Econometrica, 50, 987-1007.

[36] Estrada J. (2010). Black swans, market timing, and the Dow. Applied Financial Economics Letters, forthcoming.

[37] Fernandez V. (2006). The impact of major global events on volatility shifts: Evidence from the Asian crisis and 9/11. Economic Systems, 30, 79-97.

[38] Flannery M.J. and Protopapadakis A.A. (2002). Macroeconomic factors do influence aggregate stock returns. Review of Financial Studies, 15, 751-782.

[39] Foerster S.R. and Schmitz J.J. (1997). The transmission of US election cycles to international stock returns. Journal of International Business Studies, 28, 1-27.

[40] Franses P.H. and Ghijsels H. (1999). Additive outliers, GARCH and forecasting volatility. International Journal of Forecasting, 15, 1-9.

[41] Franses P.H. and van Dijk D. (2000). Nonlinear Time Series Models in Empirical Finance. Cambridge University Press, Cambridge.

[42] Frey B. and Kucher M. (2000). History as reflected in capital markets: The case of World War II. Journal of Economic History, 60, 468-496.

[43] Friedman B.M. and Laibson D.I. (1989). Economic implications of extraordinary movements in stock prices. Brookings Papers on Economic Activity, 2, 137-185.

[44] French K.R., Schwert G.W. and Stambaugh R.F. (1987). Expected stock returns and volatility. Journal of Financial Economics, 19, 3-29.

[45] Fox A.J. (1972). Outliers in time series. Journal of the Royal Statistical Society, Series B, 34, 350-363.

[46] Galbraith J.K. (1997). The Great Crash of 1929, Boston: Houghton Mifflin.

[47] Hammoumdeh S. and Li H. (2008). Sudden changes in volatility in emerging markets: The case of Gulf Arab stocks markets. International Review of Financial Analysis, 17, 47-63.

[48] Haugen R.A., Talmor E. and Torous W.N. (1991). The effect of volatility changes on the level of stock prices and subsequent expected returns. The Journal of Finance, 46, 985–1007.

[49] Hotta L.K. and Tsay R.S. (1999). Outliers in GARCH processes. Manuscript, University of Chicago.

[50] Inclán C. and Tiao G.C. (1994). Use of cumulative sums of squares for retrospective detection of changes of variance. Journal of the American Statistical Association, 89, 913-923.

[51] Jones S.T. and Banning K. (2009). US elections and monthly stock market returns. Journal of Economic and Finance, 33, 273-287.

[52] Kasman A. (2009). The impact of sudden changes on the persistence of volatility: Evidence from the BRIC countries. Applied Economics Letters, 16, 759-764.

[53] Kokoszka P. and Leipus R. (2000). Change-point estimation in ARCH models. Bernoulli, 6, 513-539.

[54] Mendes B.V.M. (2000). Assessing the bias of maximum likelihood estimates of contaminated GARCH models. Journal of Statistical Computation and Simulation, 67, 359-76.

[55] Mishkin F.S. (2010). Over the cliff: From the subprime to the global financial crisis. Working Paper No 16609, NBER.

[56] Mishkin F.S. and White E.N. (2002). US stock market crashes and their aftermath: Implications for monetary policy. Working Paper No 8992, NBER.

[57] Moshirian F. (2011). The global financial crisis and the evolution of markets, institutions and regulation. Journal of Banking and Finance, 35, 502-511.

[58] Ng H.G. and McAleer M. (2004). Recursive modeling of symmetric volatility in the presence of extreme observations. International Journal of Forecasting, 20, 115-129.

[59] Nierderhoffer V., Gibbs S. and Bullock J. (1970). Presidential elections and the stock market. Financial Analysts Journal, 26, 111-113.

[60] Nierderhoffer V. (1971). The analysis of world events and stock prices. Journal of Business, 44, 193-219.

[61] Officer R.R. (1973). The variability of the market factor of New York Stock Exchange. Journal of Business, 46, 434-453.

[62] Pagan A.R. and Schwert G.W. (1990). Alternative models for conditional stock volatility. Journal of Econometrics, 45, 267-290.

[63] Rangel J.G. (2011). Macroeconomic news, announcements, and stock market jump intensity dynamics. Journal of Banking and Finance, 35, 1263-1276.

[64] Rappoport P. and White E.N. (1993). Was there a bubble in the 1929 stock market? Journal of Economic History, 53, 549-574.

[65] Reilly W.B. and Lukseitch W.A. (1980). The market prefers republicans: Myth or reality? Journal of Financial and Quantitative Analysis, 15, 541-59.

[66] Rigobon R. and Sack B. (2005). The effects of war risk on U.S. financial markets. Journal of Banking and Finance, 29, 1769-1789.

[67] Rodrigues P.M.M. and Rubia A. (2011). The effects of additive outliers and measurement errors when testing for structural breaks in variance. Oxford Bulletin of Economics and Statistics, forthcoming.

[68] Sakata S. and White H. (1998). High breakdown point conditional dispersion estimation with application to S&P 500 daily returns volatility. Econometrica, 66, 529-567.

[69] Sansó, A., Aragó V. and Carrion-i-Silvestre J. (2004). Testing for changes in the unconditional variance of financial time series. Revista de Economía Financiera, 4, 32-53.

[70] Santa-Clara P. and Valkanov R. (2003). The presidential puzzle: Political cycles and the stock market. Journal of Finance, 58, 1841-72.

[71] Schwert G.W. (1981). The adjustment of stock prices to information about inflation. Journal of Finance, 36, 15-29.

[72] Schwert G.W. (1989a). Why does stock market volatility change over time? Journal of Finance, 44, 1115-1153.

[73] Schwert G.W. (1989b). Business cycles, financial crises, and stock volatility. Canegie-Rochester Conference Series on Public Policy, 31, 83-126.

[74] Schwert G.W. (1990). Stock volatility and the crash of 87. Review of Financial Studies, 3, 77-102.

[75] Schwert G.W. (1998). Stock market volatility: Ten years after the crash. Working Paper No 6381, NBER.

[76] Schwert G.W. (2011). Stock volatility during the recent financial crisis. Working Paper No 16976, NBER.

[77] Schwert G.W. and Seguin P.J. (1990). Heteroskedasticity in stock returns. Journal of Finance, 45, 1129-1155.

[78] Shachmurove Y. (2012). A historical overview of financial crises in the United States. Global Finance Journal, forthcoming.

[79] Taleb N. (2007). The Black Swan. The Impact of the Highly Improbable. Random House.

[80] Tolvi J. (2001). Outliers in eleven Finnish macroeconomic time series. Finnish Economic Papers 14, 14-32.

[81] Tsay R.S. (1986). Time series model specification in the presence of outliers. Journal of the American Statistical Association, 81, 132-141.

[82] van Dijk D., Franses P.H. and Lucas A. (1999). Testing for ARCH in the presence of additive outliers. Journal of Applied Econometrics, 14, 539-562.

[83] Voth H-J. (2003). Stock price volatility and political uncertianty: Evidence from the interwar period. Working Paper No 02-09, MIT.

[84] Wang J., Meric G., Liu Z. and Meric I. (2009). Stock market crashes, firm characteristics, and stock returns. Journal of Banking and Finance, 33, 1563-1574.

[85] White E.W. (1990). The stock market boom and crash of 1929 revisited. Journal of Economic Perspectives, 4, 67-83.

[86] Wichern D.W., Miller R.B. and Hsu D.A. (1976). Changes of variance in first-order autoregressive time series models-With an application. Journal of the Royal Statistical Society, Series C, 25, 248–256.

[87] Wigmore B.A. (1987). Was the Bank Holiday of 1933 caused by a run on the dollar? Journal of Economic History, 47, 739-755.

[88] Wolfers J. and Zitzewitz E. (2009). Using markets to inform policy: The case of the Iraq War. Economica, 76, 225-250.

[89] Zhang X. and King M. (2005). Influence in generalized autoregressive conditional heteroscedasticity processes. Journal of Business and Economic Statistics, 23, 118-129.

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